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Microstructural characterisation of thermal spray coating on stainless steel AISI 316 L

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Abstract— ***Thermal spray coating process is a surface modification technique in which a coating material like cermet's, metallic, ceramic and some other materials in form powder are feed into a torch or a gun, the powder inserted into torch will be melted by high temperature developed by torch. Coating thickness can achieve by applying multiple layer of melted coated material. This paper aims at the study of microstructural characterisation of thermal spray single layer and multi-layer coatings. Coatings on the substrate were followed by Scanning electron microscopy and X-ray diffraction to know the different phases present in the coated as well uncoated SS 316L. By seeing SEM result it's found that single layer coating is not done properly. As compared to SEM result of single layer coated AISI 316 L multilayer SEM results is more accurate, there is no crack on the coating surface and there is much less porosity in the multilayer coated sample. AISI 316L contain Nickel (Ni) and Chromium (Cr) as major phase.***

Keywords— SEM, XRD, Phases, Cracks.

I. INTRODUCTION

AISI316L is most commonly used steel in industries their application are marines, pressure vessels, heat exchangers, valves, pumps pipe lines, food related processing, medical equipment. AISI316L grade show good resistance against corrosion under normal environments conditions like in normal seawater solutions containing 35g/l NaCl in distilled water. Generally, seawater is very often described as 3.5% NaCl solution however seawater is much more complex than just simple kitchen salt solution. Composition of seawater, temperature, movement in tidal zone, salinity, oxygen concentration, and biological activity are etc differ from location to location and these are important parameters that effect the corrosion behaviours of stainless steel in seawater [1]. Stainless steel consists of various group and each one having different grade classify according to their chemical constituents [13]. The stainless steel having Fe and Cr 12 to 18 consider as ferritic steel such type of steel doesn't consist Ni.Ferritic steel consists of small amount of non heat treatable carbon but shows excellent corrosion resistance to and oxidation as compared to martensitic. Martensitic stainless steel consists of carbon0.19 to 1.1% and Cr 11 to 17% [15]. Heat treatment can be done on such materials and their corrosion resistance properties are not too good as compare to other materials having same amount of Cr and other alloy composition. Duplex stainless steel consists of copper, iron, nickel (4-7%), chromium (18-26%), and molybdenum (0-4%). It showed the microstructure of both austenitic and ferritic thus provide the properties of corrosion resistance and have greater strength [11]. Austenitic stainless steel consists of Fe, Cr 15% to 25% and Ni 5 % to 11 properties can be improved further by adding molybdenum added as per requirement. Its exhibits superior corrosion resistance properties as compared to Ferritic and Martensitic, Example of austenitic stainless steel is AISI 316L. Although stainless steel is having better as compare to corrosion resistance than any other carbon or alloy steel, but in some circumstance it can corrode [9]. It's stain-less steel not stain-impossible steel. In normal water based environment and atmospheric condition stainless steel will not corrode, but in more aggressive condition the basic type of stainless steel corrodes and more highly stainless steel is required [7].

II. EXPERIMENTAL ANALYSIS

2.1Specimens preparation for SEM test

Initially three specimens were cut out from AISI 316L sheet of square dimension having length and breadth 15 mm. One specimens is single layer coated with Inconel 718 using D-gun thermal spray method and second specimens is coated double layer using the same method and third specimens is remain pure AISI 316L in square form without any coating.

2.2 Scanning Electron Microscope (SEM) test

Scanning electron microscopies electron microscopy which produced fine images of samples by scanning the sample electron beam. Focused beam electron interacts with atoms in the specimen producing various signals which contains information about surface of sample and different chemical composition. Raster scan pattern is generally used for scanning by the electron and beam position is combined with detected to generate image. Raster scanning is a rectangular pattern of image capturing and reconstructing in television. SEM produces better resolution quality of sample images than 1 nanometre. The entire specimen must have a standard size such that it takes place in sample holder. SEM produces better resolution than the optical microscope. Specimens can be checked in low vacuum, high vacuum, in wet condition and wide range of cryogenic or high temperature.

Initially the specimen surface was cleaned properly then an electron beam having energy high energy is focused on the sample this beam is having very narrower dia. From final lens the electron beam is deflect two axis such that it can that it can scan a rectangular area over surface.

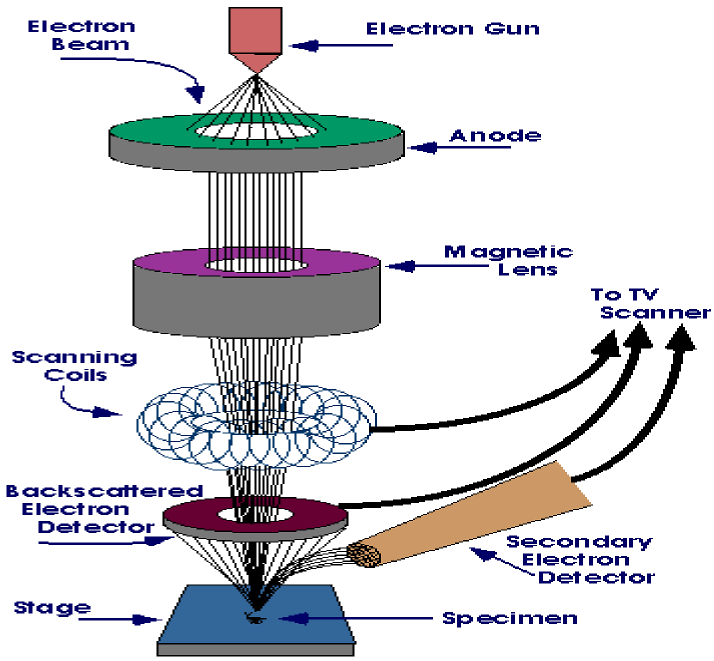

Fig.3.11 Scanning Electron Microscope Diagram

2.4 X Ray Diffraction (XRD)

XRD is technique designed to provide more in details information about crystalline compounds, identification and quantification of crystalline phase. It can also be used to find the proportion of different minerals or many other substances that are present in the mixture. By using this method the atoms size, length and chemical nature can be determined for various materials.

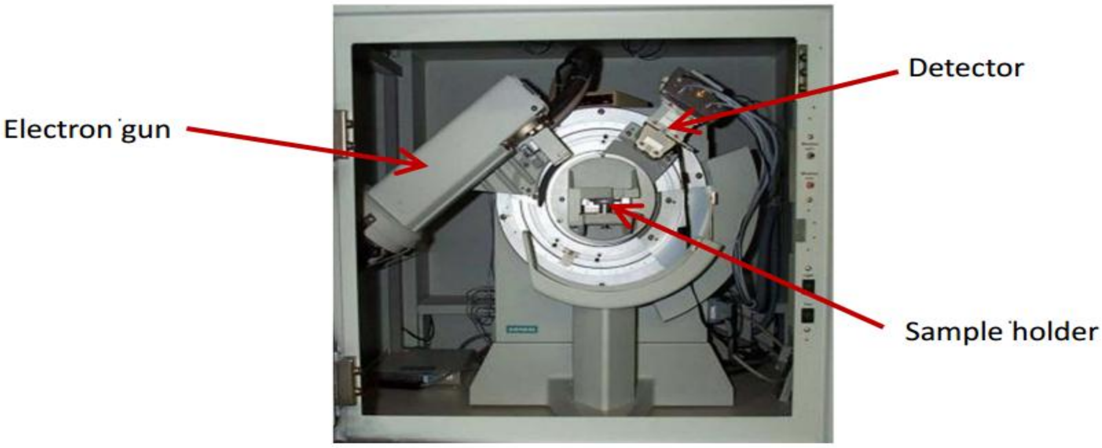

Fig 3.12 show the XRD machine

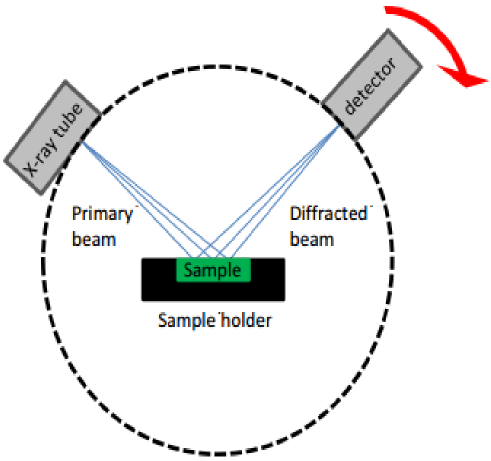

Fig.3.13 Classic reflection geometry.

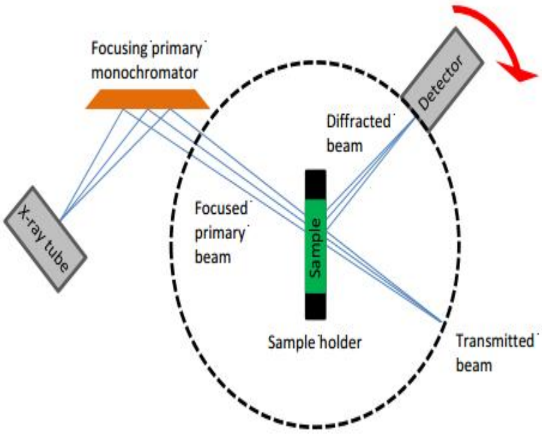

Fig. 3.14 Classic transmission geometry.

Two principal method for X-ray generation:

- First- Fire a beam of electron at metal surface. Ionization of inner shell electron result in formation of electron hole. Relaxation of electrons from upper shell, the energy difference delta E (10^{10}m) escapes in form of X-ray of specific wave length. Commonly used metals are Cu and Mo. Very inefficient method most energy dissipated as heat thus require permanent cooling.
- Second- Accelerate electron in a particle accelerator, Electron accelerated at relativistic velocities in circular orbits. As the velocity reach the speed of light they emits electromagnetic radiation in the X-ray region.
-

III. RESULTS

3.1 SEM TEST

SEM test will give the brief discussion about the surface characteristic of specimens before and after the corrosion test. With the help of SEM test surface characteristics like porosity, wears, un-melted powder particles, cracks, and pits etc. are study briefly.

SEM test is used to find out reason for different surface properties of similar sample, like if two same coated samples and if surface of one coated sample corrode more rapidly as compared to another than by using SEM test reason for this is find out.

Below figure3.1show the SEM result of single layer Inconel 718 coated stainless steel sample at magnification of 2000mg. Different surface properties like cracks, porosity, and semi-melted coating powder are noted in

Figure. By seeing SEM result it's found that single layer coating is not done properly. This is why data collected from corrosion resistance showed no weight loss different between stainless steel and coated stainless steel. Because of cracks corrosion resistance properties of coated stainless steel are affected in negative manner, both coated stainless steel and uncoated stainless steel loss same 0.0002 gram of weight after taking out the specimens from stagnant seawater.

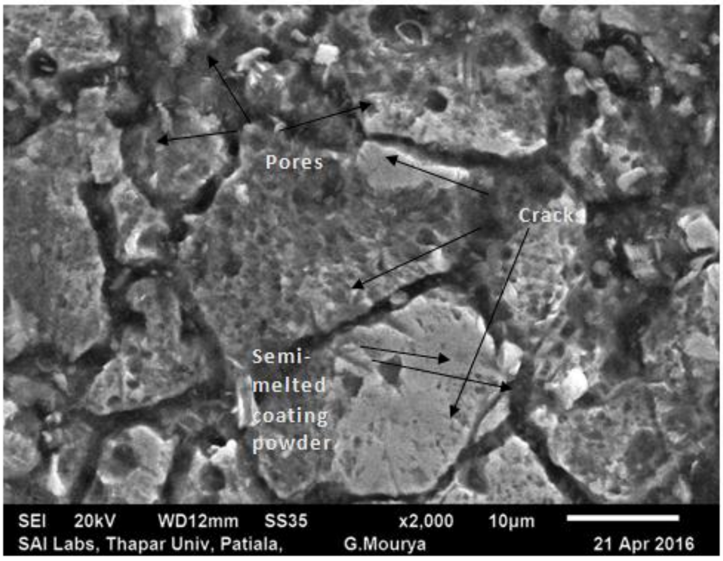

Figure 3.1 SEM result of single layer coated sample before corrosion test

Figure 3.2showed the SEM result of multilayer coated AISI 316L with Inconel 718 powder. Details description about the surface structure of multilayer coated AISI 316L are shown in figure. As compared to SEM result of single layer coated AISI 316 L multilayer SEM results is more accurate, there is no crack on the coating surface and there is much less porosity in the multilayer coated sample. Because of very less crack in coating surface and dense coating corrosion resistance properties of multilayer sample is much greater than single layer coated sample and uncoated stainless steel sample. Bonding between the coated powders are good and it's shown by dense regions.

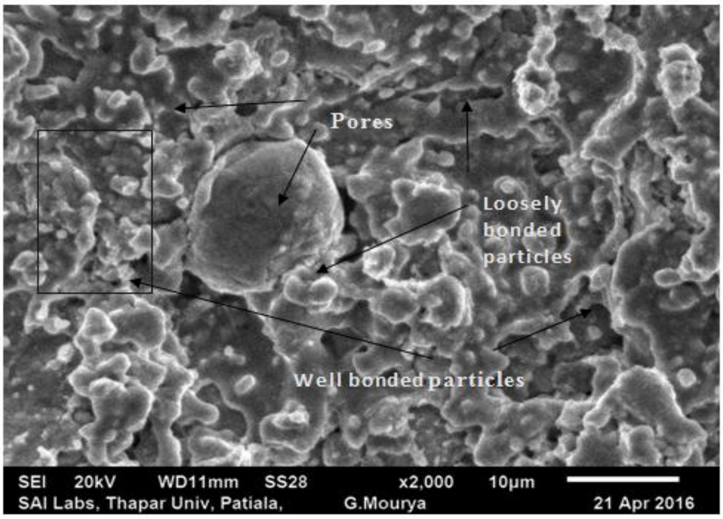

Figure 3.2 SEM result of multilayer coated sample before corrosion test

Figure 3.3 showed the SEM result of stainless steel AISI 316L at 2000 magnification after corrosion test in stagnant seawater. By observing the SEM result it is noted that stainless steel surface contains lots of up and downs, this is because of materials removed from that place some pits are also observed in the figure. Materials removals and pitting formation was occurred because specimen is dipped in stagnant seawater for 96 hours.

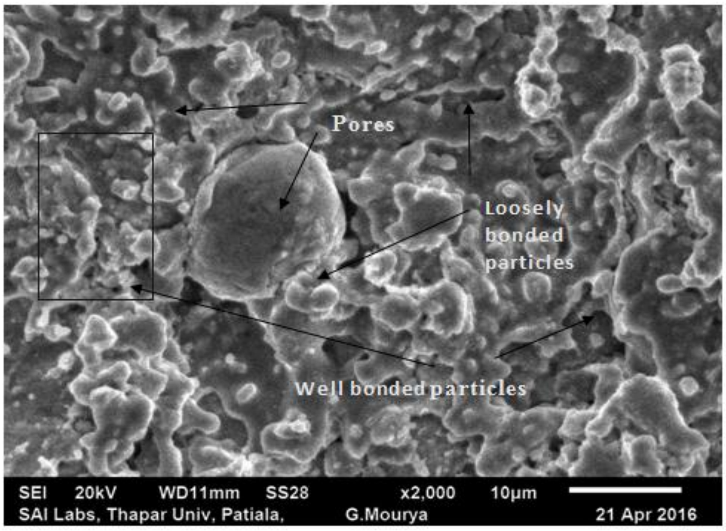

Figure 3.3SEM result of multilayer coated sample before corrosion test

Figure 3.4 showed SEM result of single layer coated stainless steel AISI 316L at 2000 magnification after corrosion test in stagnant seawater for 96 hours. Particles removed and pits are clearly seen in the figure. Comparing figure 11 and 12 in both the figure, weight loss or particles removed are almost same but pits is generally more in figure 11 i.e. in uncoated stainless steel sample pits are more.

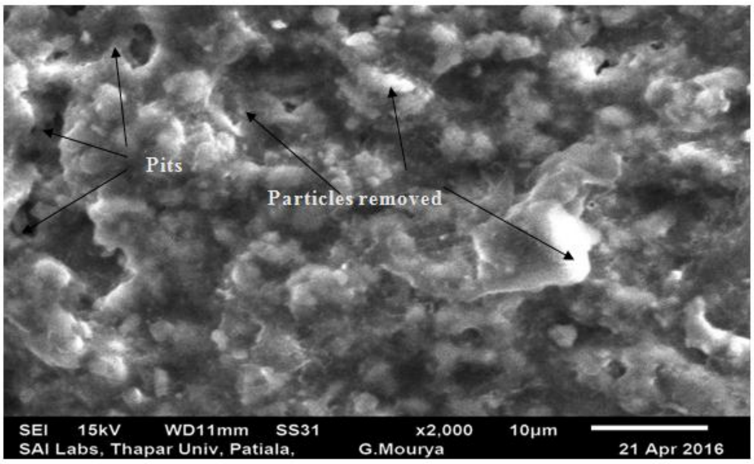

Figure 3.4 SEM result of single layer coated AISI 316L after corrosion test

Figure 4.5 showed SEM result of multilayer coated stainless steel AISI 316L with Inconel 718 powder after conducting corrosion test on the specimen for 96 hours. SEM result was recorded at 500 magnifications. From figure it is noticed that particles removed is very less and pitting observed is also very less as compared to another specimen.

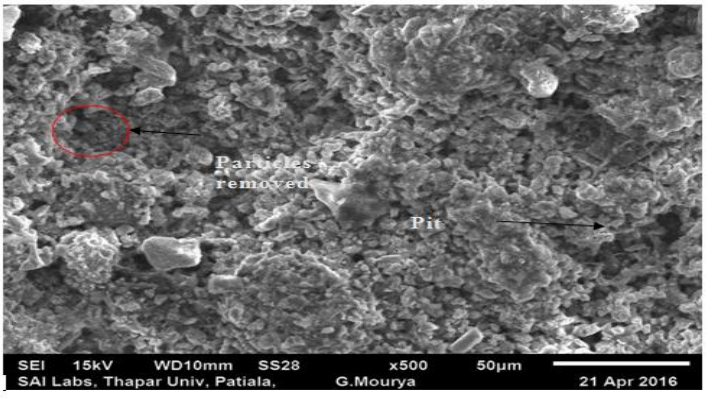

Figure 4.5 SEM result of multilayer coated AISI 316L after corrosion test

Comparing all the three specimens of after corrosion test it was found that particles removed are same in uncoated stainless steel and single layer coated stainless steel but in case of multilayer coated stainless steel particles removed are very less as compared to both specimens. More number of pits are formed on uncoated stainless steel as compared to single layer coated specimen and multilayer coated specimens.

4.4 X-Ray Diffraction

In this paper X-ray diffraction of two sample was done, first uncoated SS AISI 316L and coated SS AISI 316L with nickel alloy Inconel 718, coating was done by detonation gun method. Figure 14 showed the XRD image of stainless steel AISI 316L.

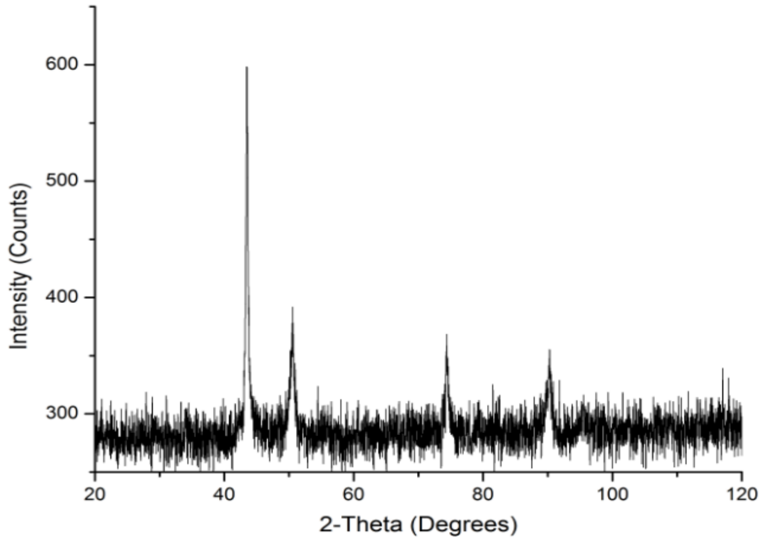

Figure 4.6 XRD image of AISI 316L

In figure 4.6 the peak corresponding of graph is belonged to nickel and chromium because these two components are the major constituents of stainless steel AISI 316L.

Figure 4.7 showed the XRD result of stainless steel AISI 316L coated with nickel alloy Inconel 718 by using detonation gun method.

Inconel 718 contain Nickel (Ni) and Chromium (Cr) as major phase, figure 4.15 so the X-ray diffraction pattern of thermal sprayed coated Inconel 718 on stainless steel AISI 316L. As it is observed from the graph that peak corresponding to the present of nickel as major phase.

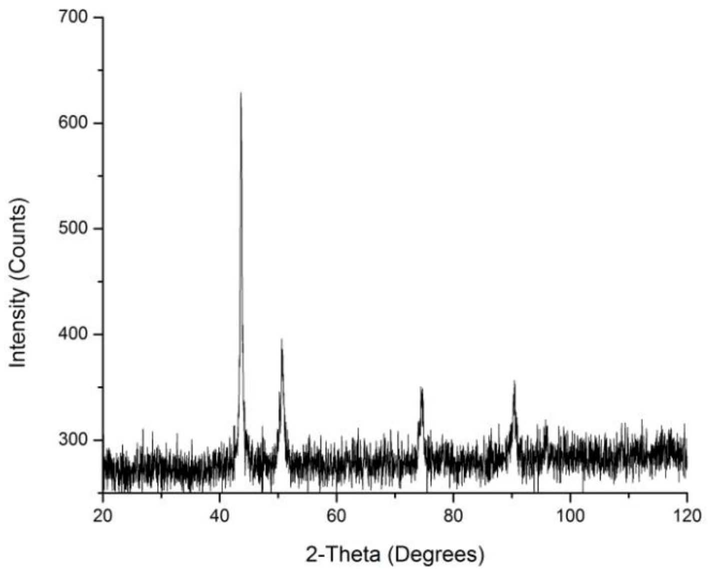

Figure 4.7 XRD result of coated stainless steel with Inconel 718

Graphs of uncoated stainless steel and coated stainless steel are somewhat similar because of chemical composition of stainless steel AISI 316L and coating powder used i.e. Inconel 718. Both Inconel 718 and stainless steel AISI 316L have higher percentage of nickel and chromium chemical in their respective chemical composition. Thus the face formed in coated and uncoated stainless steel are similar but not same because Inconel 718 have 50% to 55% nickel and chromium 17% to 21% whereas in stainless steel AISI 316L in only 10% to 14% nickel and 16% to 18% chromium.

IV. CONCLUSIONS

1. SEM test was conducted in this paper which help in studying the different characteristic of coating and un-coating specimens it's also help in study the corrosion behaviours of uncoated stainless steel AISI 316L and coated AISI 316L.
2. XRD test was also conducted to know the different phase generated in uncoated AISI 316L and coated AISI 316L. XRD results of uncoated AISI 316L and coated AISI 316L are similar because coating materials Inconel 718 and base materials AISI 316L have nickel and chromium is in maximum percentage in their chemical composition.

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